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RESEARCH COUNCIL OF ALBERTA

PRELIMINARY REPORT 63-1

Earth Science Report

AQUIFER-TESTING PROCEDURES AND OTHER INFORMATION USED IN EVALUATING GROUNDWATER SUPPLIES IN ALBERTA

by

J.F. Jones

Price 50 cents

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J. F. Jones

Research Council of Alberta
Edmonton, Alberta
1963

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AQUIFER-TESTING PROCEDURES AND OTHER INFORMATION USED IN EVALUATING GROUNDWATER SUPPLIES IN ALBERTA

ABSTRACT

The following topics are discussed in this report: the general occurrence of groundwater in Alberta; types of aquifers; water-well-log data importance and groundwater quality. Included are appendices outlining aquifer-testing procedures, methods of taking water-level and flow measurements, groundwater information available from the Research Council of Alberta, some pertinent groundwater terminology and useful conversion tables.

It is hoped that this information will enable engineers, geologists, well contractors, and other people concerned with the development of groundwater supplies to carry out sound planning for the utilization of these valuable resources.

INTRODUCTION

Many factors have to be considered if water wells are going to be used to supply a city, town, industry, hamlet or farm. It is of importance to know, for instance, whether more than one well will be required; at what rate the well can be safely pumped; whether the well will be taking more water out of the ground than is being replaced; how long the well will last and what is the temperature and quality of the groundwater. In order to answer these questions, the following outline has been prepared so that engineers, well contractors, and other people concerned with the development of groundwater supplies will know what type of basic information is required in order to evaluate groundwater resources and plan soundly for their use.

GENERAL OCCURRENCE OF GROUNDWATER IN ALBERTA

Groundwater has been defined by Meinzer (1923a) as that part of the subsurface water which is held in the zone of saturation. In the zone of saturation all the pore spaces and cracks in the rocks are filled with water. The top of the zone of saturation is called the water table. Above the water table, in the zone of aeration, water is still present, but it is held by earth materials in such a manner that it can be utilized only by plant growth.

The source of groundwater is rain and snow that falls on the surface of the earth. Most of this water runs off the land and is eventually returned to the atmosphere by evaporation and transpiration. A good portion, however, percolates downward through the pores and crevices of many different kinds of earth materials and reaches the zone of saturation, thus recharging the groundwater reservoir.

In order that a water well may be successful, a borehole must penetrate earth material that carries water and can transmit it readily. Such earth material is called an aquifer. The ability of an aquifer to store and transmit water depends primarily on two of its properties - its porosity and its permeability. Porosity is the percentage of pore space or void in a given volume of rock or soil, while permeability is a measure of the ability of a rock or soil to transmit a fluid. Where a water-bearing formation has many interconnected pores and water can move readily, the formation is said to be both permeable and porous.

In the Alberta plains region, the water-bearing zones or aquifers show considerable variation in these properties. The nature and extent of these aquifers varies from place to place in the province. The most common types and their hydrologic characteristics are listed below:

1. Clean well-sorted sands and gravels transmit water the best and as a consequence it is common to search for them when large capacity wells -100 gallons per minute (gpm) and more - are required.

2. Consolidated sandstones in the bedrock have a much lesser ability to transmit water than most sand and gravels. Their permeabilities depend upon the degree of cementation or the amount of fine material in the pore spaces between the sand grains. All gradations exist from clean, well-sorted sandstones with fair to medium production of groundwater, to silty and shaly sandstones with little or no production. In the Alberta plains, wells completed in sandstones seldom produce more than 100 gpm and generally produce between 1 and 20 gpm.

3. Locally, a formation will yield water even though it has little or no pore space. Sometimes, for example, a cemented sandstone with a low percentage of pore space is fractured and creviced and thus is sufficiently capable of transmitting water to be an aquifer. Similarly, some well-fractured coal seams are good aquifers.

Water Table or Unconfined Aquifer

Groundwater is said to be under water table or unconfined conditions when there is no impermeable confining bed between the aquifer and the land surface and the water is at atmospheric pressure at the free water surface. Where the water table intersects the surface of the land groundwater is discharged through springs. The water-table level does not remain constant but fluctuates depending upon the amount of groundwater gained or lost due to changes in the relationship between recharge and discharge. A perched water table condition results when water accumulates over impermeable strata lying above the general water table.

Artesian or Confined Aquifer

Where an aquifer, such as a water-bearing sandstone, is overlain by less permeable strata, such as shale, the water in the sandstone may be confined and under pressure. If the water level in a well drilled into it rises above the top of the aquifer, the well and the aquifer are termed artesian. If the pressure is sufficient to make the water rise above the ground level, the well is called a flowing artesian well.

Aquifers of Importance in Alberta

In the Alberta plains region there are many kinds of aquifers important in the development of groundwater resources. These can be divided into two major types, those found in the bedrock and those found in the overburden.

The bedrock underlying the plains region consists essentially of a series of sandstones and shales with all gradations between. The formations concerned in the development of groundwater supplies are mainly late Cretaceous and Tertiary in age. The important aquifers are found in the sandstone members, with coal seams occasionally providing a source of groundwater.

Important aquifers are associated also with the overburden or surficial deposits that overlie the bedrock. Sand and gravel terraces along recent streams and rivers often provide large quantities of water. Sand and gravel aquifers are found associated also with glacial deposits and in preglacial bedrock channels or "buried channels" covered by more recent deposits. Examples of these types of aquifers are shown in figure 1.

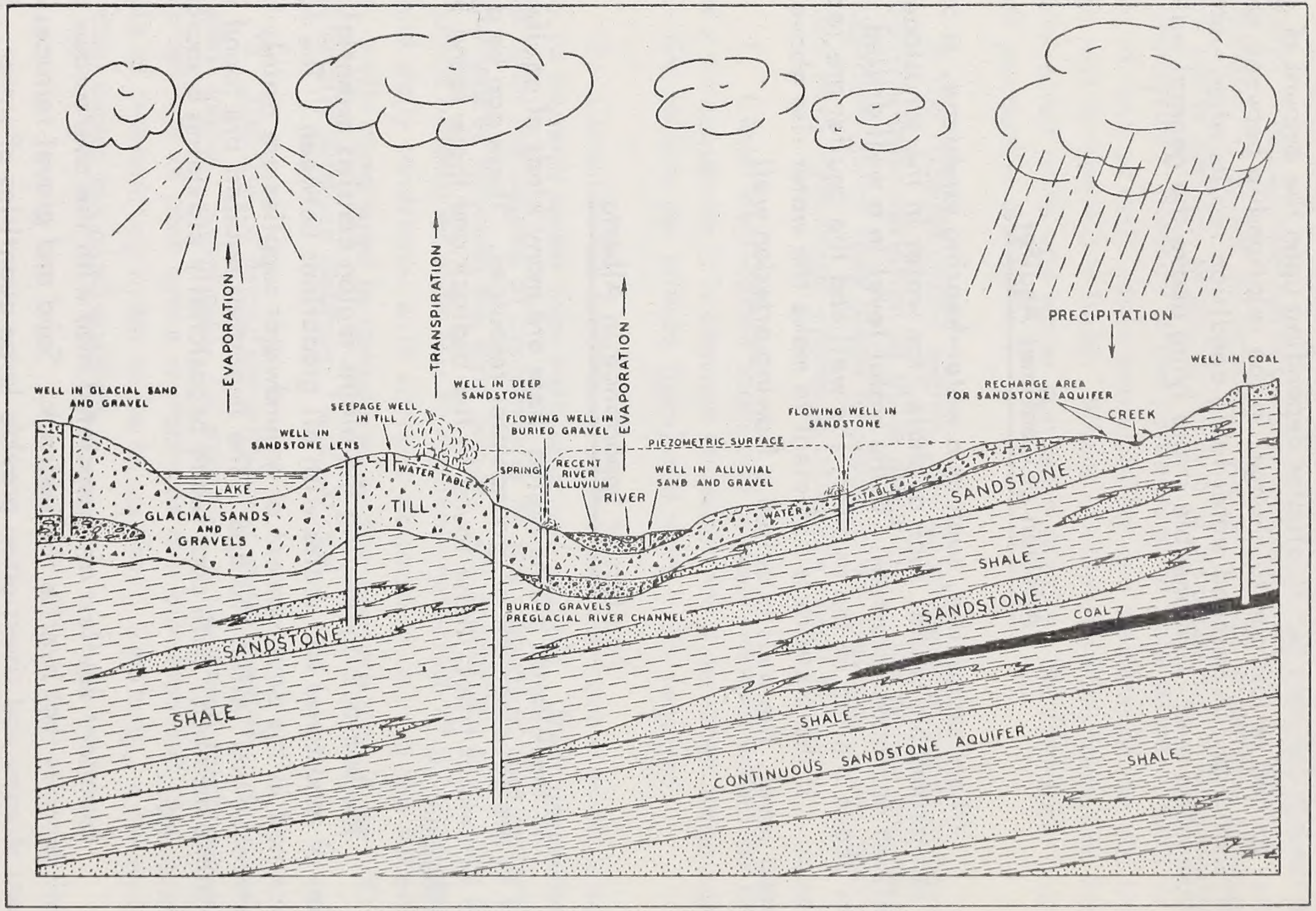


Figure 1. General occurrence of groundwater, Alberta Plains

WATER-WELL LOGS

For the evaluation of a water supply from a well one of the most important pieces of basic information is an accurate log of the different materials penetrated while drilling the well. All water-well drillers are required to send well logs to the Water Resources Branch, Provincial Department of Agriculture, and the information on these logs is transferred to the Cardex filing system at the Research Council. Since 1957 most of the information concerning water wells drilled in the province has been collected, but little information is available concerning wells drilled prior to this date.

It is very important that every driller's log contain the maximum amount of information. Most of this information can only be supplied by the driller at the time the well is being drilled, and if it is not recorded then, it may be lost forever. Figure 2 is a copy of a water well driller's log. All the information requested on the log form is important but in work with logs sent in by many different drillers, the following items are commonly incomplete.

1. Location of Well - This is the most important item on the log. Without it, the log is worthless. Every well or test hole drilled should be located by legal subdivision or quarter, section, township, range, and meridian. In addition, when wells are drilled within a town, village or subdivision, every effort should be made to obtain the lot and block number. The elevations of all wells should be recorded on the log in feet above sea level. Where there are other nearby wells, particularly within a municipality, the elevation of the well in relation to other wells should be also noted if possible.

The system of survey of lands used in the Province of Alberta is explained in the following excerpt, obtained from the "Schedule of Wells Drilled for Oil and Gas in 1960", Oil and Gas Conservation Board, Province of Alberta.

" Townships are six miles square, with road allowance in addition. A road allowance 66 feet wide is left on the east side of every section and either on the north or south of each section, there being a road allowance on the south of the township, and every two miles northward. Sections are numbered as follows: "

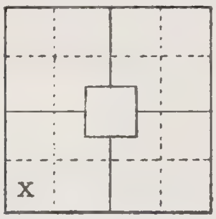
WATER WELL DRILLER'S REPORT
Dept. of Water Resources

1. Original to: Dept. of Water Resources

A. OWNER OF WELL:
Name George Dott
Address Box 123, Cardium, Alta.
Location of Well:

DRILLER:
Name I. M. Driller
Address R.R. 2, Valentine, Alta.
Permit No. 456 Year 1962

LSD ¼ SW Sec. 7 Twp. 58 Rge. 10 W.6 M. Well completed 14 Month Feb. 1962



1 square mile
Estimated from topographical map

Show well location with an "X" in diagram at left.
Elevation 2250 feet
(Map X Altimeter
Surveyed ....)

B. Type of well: dug .... bored .... drilled X (rotary X (cable tool ....
other ....
Total depth below surface: 250 ft. Diameter 4 3/4 in.
Casing: 4 1/2 in. to 220 ft.: ..... in. to ..... ft.
How casing set: cemented X driven ... loose ... packer ...
Well finish: open hole ..... slotted casing ..... screen X
other .... size of slots or screen # 20 slot Johnson
Type of pump Submersible Pump setting below surface 220 ft.
Size of pump 2 1/2"

C. Water occurrence and tests:
1. Water at 220 ft. to 227 ft. below surface.
Rose to 40 ft. below surface.
~~Bailed or~~ Pumped at 15 g.p.m. for 3 min. ~~hours.~~
Drawdown 80 ft. in 3 min. hours.
Recovered to 39.5 ft. in 2 1/2 min. hours.
2. Water at 220 ft. to 227 ft. below surface.
Rose to 39.5 ft. below surface.
Bailed or Pumped at 20 g.p.m. for 8 min. hours.
Drawdown 100 ft. in 8 min. hours.
Recovered to 39.0 ft. in 10 min. ~~hours.~~
Well development: surged X acidized ....
flushed X other ....
Water level when well completed (from surface) 38.5 ft.
Remarks: ....

D. Quality of water:
Color: none X red ..... brown ..... other ....
Odor: none X gas ..... sulphur ..... other ....
Turbidity: clear X silty ..... sandy ..... cloudy ....
Type: soft ..... medium hard X ..... hard ....
Impurities: iron X alkali ..... sulphate ..... other ....
Use: domestic X stock (no. 20) - ....
industrial (well no. ....) ....
town supply (well no. ....) ....
other ....
Was water supply satisfactory? yes X no ....
If no, give reason ....

Stratigraphic Log		
From ft.	To ft.	Description
0	8	fine brown silty sand
8	25	brown clay with boulders
25	108	blue-gray clay with boulders
108	177	black shale
177	203	yellow-brown siltstone
203	204	coal
204	208	grey sandstone, hard
208	220	green shale
220	227	light grey coarse-grained sandstone
227	250	brown shale

Well bottomed in:
shale X sandstone ... coal
loose sand ..... gravel
other ....
Depth to top of bedrock 108 ft.

Fig. 2. Typical water well log

31	32	33	34	35	36
30	29	28	27	26	25
19	20	21	22	23	24
18	17	16	15	14	13
7	8	9	10	11	12
6	5	4	3	2	1

"Townships are numbered from the International Boundary northward. The east boundary of Alberta is the fourth principal meridian and it marks the 110th degree of longitude, west of Greenwich. The fifth meridian is at 114 degrees, and the sixth at 118 degrees west of Greenwich. Ranges are numbered westward from each initial meridian the last range abutting the next meridian being fractional. The north boundary of every township divisible by 4 is a base line, and sections along the base lines are a full mile wide. Going northward for 12 miles, each section narrows slightly until a correction line is reached, and going south each section widens slightly until the correction line is reached."

"Sections may be divided into 16 legal subdivisions and numbering of these subdivisions is prescribed as follows:"

13	14	15	16
12	11	10	9
5	6	7	8
4	3	2	1

2. Casing - The diameter and length of casing should be noted. Additional information such as liners, surface casing, fittings such as a flange or collar, on the top of a liner, welded or threaded casing should be noted on the back of the log, particularly for municipal wells. This information is of particular value to the well owner and the driller if it is necessary to do a workover job.

3. Screen - The size of the slot openings of a well screen should be listed. Other information, such as length, diameter, and make of well screen should be noted as additional information on the back of the log.

4. Type of Pump - The type of pump, its setting and size should be recorded. Final pumping rate of installed pump, though not required on log, should be noted. If no pump is run, the pump setting and pumping rate recommended by the driller should be recorded on the log.

5. Water Occurrence and Tests - Each occurrence of water and each pump or bail test should be recorded separately.

6. Quality of Water - In addition to such information as color, odor, turbidity, etc., required on the log form, it is a good practice to take a water sample and have it analyzed for its chemical and bacteriological quality (see section on groundwater quality). If such analyses are available, a copy could be attached with the log form or written on the back of it.

7. Stratigraphic Log - This is the most important item on the log, so far as geological studies are concerned. The log should be the most accurate possible description of the materials penetrated during drilling. Variations in color and hardness, formation changes and anything that is unusual should be reported.

8. Temperature - Measurements of the temperature of the water pumped from a well should be made during a pumping test. This information is not required on the log, but when available should be noted on the back of the log form.

GROUNDWATER QUALITY

The chemical quality of groundwater shows considerable variation throughout Alberta and depends on the type of material that the groundwater has encountered in its migration to the water-bearing zone. The amounts of the individual and various combinations of the dissolved mineral constituents are usually expressed in water analyses as parts per million (ppm).

Generally in Alberta hard waters occur in glacial and Recent deposits, and soft waters in the bedrock. Fresh water percolating downward through the glacial materials picks up calcium and magnesium. When this hard water enters bedrock containing a high content of the clay mineral montmorillonite, the calcium and magnesium are exchanged for sodium and the water becomes

softer, the softness depending upon the length of time and degree of contact with the montmorillonite. Many domestic wells are drilled through glacial deposits containing hard water in search of softer water in the bedrock.

Hardness

The hardness of water is dependent on the concentration of calcium and magnesium sulfates or bicarbonates. Hardness is of two types, temporary and permanent. Temporary hardness is caused by the bicarbonates of calcium and magnesium, which precipitate on boiling. Permanent hardness is caused by the presence of the sulfates of calcium and magnesium, which cannot be removed by boiling. Temporary and permanent hardness are not distinguished in most water analyses, which are usually expressed in terms of hardness in parts per million of calcium carbonate.

Sulfates

The sulfates referred to in most Alberta water-analysis reports are those of calcium, magnesium and sodium. Hydrated magnesium sulfate, commonly known as "Epsom Salt", if present in large amounts, has a pronounced laxative effect on persons unaccustomed to it.

Chlorides

Chlorides are generally expressed as sodium chloride (common salt). They are commonly found in all waters. Usually no taste is imparted unless concentrations of over 300 ppm are present in the water.

Sodium

Sodium carbonates and sulfates are very common in Alberta groundwater. Sodium sulfate combines with water to form what is known as "Glauber's salt" and excessive amounts make the water unsuitable for drinking purposes. Sodium carbonate, commonly known as "black alkali", is usually associated with soft waters.

The amount of sodium (soda) is generally expressed in grains per gallon (gpg). In excessive amounts sodium is harmful to plants and corrosive to aluminum. The recommended upper limit for soda concentration in water is usually established at about 50 gpg.

Alkalinity

Alkalinity generally represents the content in parts per million of carbonates, bicarbonates and hydroxides in water. The nature of the alkalinity is shown by the various cations that are listed, such as calcium, magnesium and sodium.

Iron

Excessive amounts of iron are objectionable in a water supply because they stain clothing and plumbing fixtures, and often cause bad tastes and odors. Combined with sulfates they will corrode ferrous metals and brass. Although iron is present in most waters, only amounts in excess of 0.3 ppm are undesirable.

Nitrates and Nitrites

Nitrates and nitrites indicate the presence of organic matter in the water and in large quantities may indicate that the water supply is being contaminated in some manner.

Fluorides

Fluorides are commonly found in natural waters and are desirable for the prevention of dental caries. The suggested permissible limit for fluorides in water has been established at 1.0 ppm.

Water-Sample Analyses

Water-sample containers for taking water samples for chemical and bacteriological analysis can be obtained from the local health unit, or from the Provincial Laboratory of Public Health, University of Alberta, Edmonton, Alberta. A list of health units and their addresses is provided in Appendix D.

AQUIFER PUMP-TESTS

The rate at which water can be withdrawn from a well is dependent upon several important factors such as the permeability of the aquifer, the thickness of the water-bearing zone, the hydrostatic head or the height above the aquifer to which water will rise in the well, the efficiency of the well and the geological environment of the aquifer.

Under both water-table (unconfined) and artesian (confined) conditions the hydrostatic head in the immediate vicinity of the well lowers

during pumping and a zone of reduced pressure is produced within the aquifer around the well. This zone, or cone of depression as it is usually called, expands as pumping continues and eventually may extend for a considerable distance, lowering the water levels in neighboring wells and reducing the pressure in the aquifer until equilibrium is established, at which time the amount of water withdrawn from the system is balanced by the amount of water coming into the system. In some cases equilibrium is reached quickly, in others it may take considerable time or may never be reached. If more water is taken out of the system than is replaced by natural or artificial recharge, the aquifer will eventually be depleted.

To determine the amount of water that can be transmitted by a water-bearing formation to a well, a properly organized and carefully run pump test has to be carried out. This involves pumping a well at some constant measured rate and observing the behaviour of the water levels in the pumping well and in nearby nonpumping or observation wells that are drilled into the same aquifer. Some typical pumping and observation-well arrangements are presented in figure 3.

From such information it is possible to determine at what rates the well or wells can be pumped in the future, thus ensuring that an orderly development program can be established to develop the groundwater resources. The procedure for conducting aquifer pumping tests is outlined in Appendix A.

Pump Tests in Confined Aquifers

To evaluate the hydrologic conditions and determine aquifer coefficients in a confined aquifer, generally a minimum of one pumping well and one observation well is required. Common confined aquifers are sandstone or coal beds, and buried channel deposits of sand and gravel. In some cases more observation wells may be necessary, especially when hydrologic boundaries are encountered. The minimum length for the test should be 48 hours.

Pump Tests in Unconfined Aquifers

When a well in an unconfined aquifer is pumped, part of the aquifer is actually dewatered to provide water to the well. The most common aquifers of this type are the sands and gravels in alluvial terraces adjacent to rivers and streams in which the water table fluctuates with changes in river or stream flow.

The arrangement of the observation wells about a pumping well completed in an unconfined aquifer is more complex than that for a confined aquifer and requires more observation wells, the number depending upon the geologic and hydrologic situation.

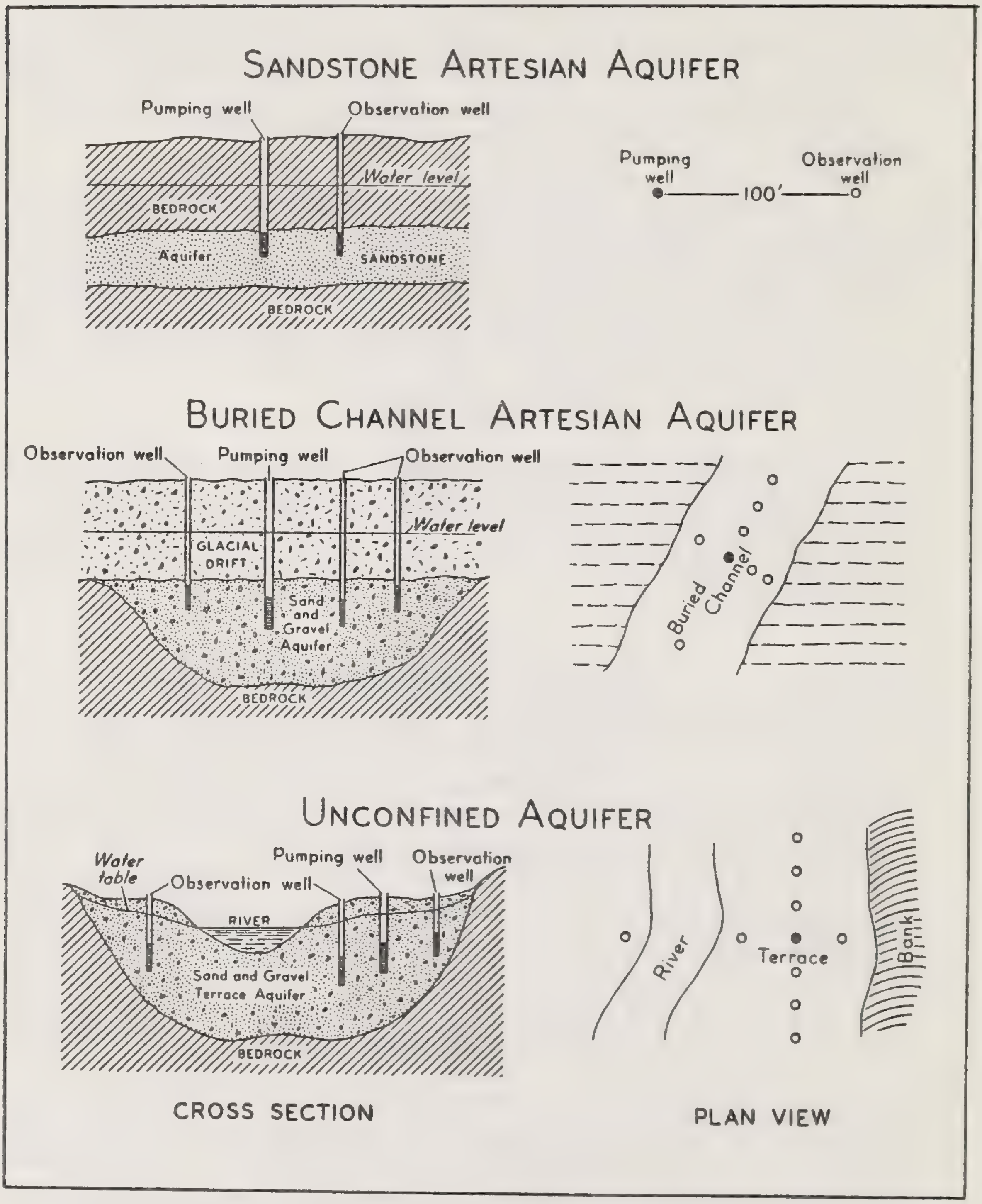


Figure 3. Typical pumping- and observation-well arrangements

There is no set minimum length of time a pumping test has to be carried out for an unconfined aquifer. Measurements of the drawdowns of the water levels in the pumping and observation wells have to be taken for a sufficient period of time to ensure that equilibrium conditions have been established, that is, that the water levels have become stabilized, usually for a minimum period of 24 hours. The total length of a pumping test in an unconfined aquifer may range from several days to a week or more. Only after the necessary basic data have been collected can a well or system of wells be satisfactorily designed.

Step-Drawdown Pump-Tests for Well Efficiency

To evaluate the efficiency of a water well and its degree of development, a step-drawdown test (Bruin and Hudson, 1958) is usually carried out on the completed production well after the constant-rate pumping test. This is a short 3-hour test. The procedure is outlined in Appendix A.

The information obtained from the step-drawdown test will indicate whether more development should be carried out in order to obtain maximum efficiency, or whether the well is being pumped at too high a rate, thus causing turbulent flow.

Bail Tests

After a test hole for groundwater is drilled, a bail test is generally performed by the driller to obtain an initial estimate of the productivity of the aquifer. Usually, however, a bail test does not provide sufficient information concerning the behaviour of the aquifer at high pumping rates under conditions of continuous production. It is nevertheless very useful in indicating whether the aquifer is worth pump testing for most municipal and industrial groundwater use, and what pump setting and pumping rate are probably required to test the aquifer adequately. The bail test is particularly useful for farm wells and wells of low yield. Furthermore, bailing a well is a widely applied method of "cleaning a well up" or developing it. Drilling mud, cuttings and muddy water are removed from the walls of the hole and from the aquifer adjacent to the hole, thus permitting water to flow more readily into the well. See Appendix A for bail-test procedure.

Interpretation of Aquifer-Test Data

The interpretation of aquifer-test data is beyond the scope of this report and the readers are referred to publications by Bruin and Hudson, (1958); Todd, (1959); Walton, (1960); and Ferris, Knowles, Brown, and Stallman, (1962).

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APPENDIX A. AQUIFER-TEST PROCEDURE

The most important factor in running a good pumping test is to obtain a pump that will produce at a constant rate with a lift equal to the pump setting at the maximum available drawdown in the well. The desired pumping rate may be calculated from bail-test results or estimated from previous production records and well history.

If the pumping rate varies by more than 5 per cent during the test the results cannot be reliably interpreted. Another important factor is that any wells within 1000 feet which are producing a significant amount of water, particularly if production is intermittent, will also interfere with the test and may make the results obtained impossible to interpret. If at all possible, arrangements should be made to have such wells either shut down or produce at a constant rate for several days before the pumping test is to be started. If this cannot be done, the effects of nearby pumping wells on the water level in the well to be pumped should be observed for 2 to 3 days before the test begins, by taking periodic water-level measurements by the wetted-tape method.

Pump-Test Procedure

1. Measure the static water level in the well to be pumped, and in all observation wells, every 2 to 3 hours for 24 hours preceding the test to determine the magnitudes of water-level fluctuations. Use the wetted-tape method if at all possible and record the depths to water and exact times of the measurements on a log sheet, in appropriate columns.

2. Measure the static water-levels immediately before the test starts.

3. Start the pump and record the exact time. This time is zero time (t = 0) and all later times are measured from it. Measure the depths to water, and record the exact time that each measurement is taken, spacing the measurements, if possible, in the following manner:

   a. every minute from 1 to 10 minutes
   b. every 5 minutes from 10 to 30 minutes
   c. every 10 minutes from 30 minutes to 1 hour
   d. every 15 minutes from 1 hour to 2 hours
   e. every 30 minutes from 2 hours to 4 hours
   f. every 60 minutes from 4 hours to 12 hours
   g. every 120 minutes from 12 hours to 24 hours
   h. if the test is longer than 24 hours, take measurements every 4 hours until 36 hours, and every 6 hours until 48 hours.

For confined aquifers, the pumping test will usually end at 48 hours, but for unconfined aquifers it may take several days or longer to establish the equilibrium conditions that are necessary when treating data from such aquifers. Water-level measurements should be taken every 12 hours after 48 hours until the end of the test if the aquifer is unconfined. Figures 4 and 5 are examples of typical pump-test data.

4. Pumping should continue at a <u>constant rate</u> for the duration of the test. If field conditions make it impossible to run the test at a constant rate for the recommended period of 48 hours in the case of a confined aquifer, a shorter test may provide sufficient information.

5. When the pump is shut off, start taking water-level measurements immediately to determine the rate of recovery, following the same measurement schedule used for pump testing. This is particularly important if the pumping rate has varied slightly during the course of the test, as the average pumping rate can be used with these data, thus minimizing any errors that might have been introduced. Recovery measurements should be taken for a minimum period of 12 hours and preferably until the water levels approach the original nonpumping or static levels. See figure 6 for an example of such recovery data. This information, properly collected, can be used in the design of the well system.

RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water-Level Measurements (field)

Location of project: Town of Cardium, Alta. Test conducted by: Big Well Drilling Ltd. Measured by: J. H. George
Well location: Lsd. or 1/4 SW Sec. 7 Tp. 58 R. 10 Mer. W. 6th
Status: Pumping well #1 (pumping or observation well) R = 0' (distance from pumping well in feet and direction) Date June 1, 1962 Page 1
Lot 3, Block 7

Date	Time hrs. & mins.	Elapsed time in mins.	Tape Reading at: Meas. Point	Tape Reading at: Water Level	Depth to water in feet	Draw-down in feet	Q = discharge gpm		Remarks (i.e. pump adjustments, water temp., static level, etc.)
May 31	6:00 pm		17.00	1.39	15.61				Static or nonpumping level measured
	7:00 pm		17.00	1.58	15.42				with a steel tape
	10:00 pm		17.00	1.70	15.30				
	12:00 pm		17.00	1.71	15.29				
June 1	6:00 am		17.00	1.73	15.27				Pump set up previous day, discharge
	7:00 am		17.00	1.73	15.27				set at 45 Imp. gpm.
	8:00 am		17.00	1.73	15.27				
	8:30 am		17.00	1.73	15.27				
	8:55 am		17.00	1.73	15.27				
June 1	9:00 am	0	17.00	1.73	15.27		45		Start pump test
	9:01	1	17.00	0.5	15.5	1.2			Measurements on pumping well with
	9:02	2	20.0	3.1	16.9	1.6			electric tape
	9:03	3	20.0	2.8	17.2	1.9			
	9:04	4	20.0	2.7	17.3	2.0			
	9:05	5	20.0	2.3	17.7	2.4	45		1 minute to fill 45 gallon drum
	9:06	6	20.0	2.2	17.8	2.5			
	9:07	7	20.0	2.1	17.9	2.6			
	9:08	8	20.0	1.9	18.1	2.8			
	9:09	9	20.0	1.8	18.2	2.9	45		1 minute to fill 45 gallon drum
	9:10	10	20.0	1.7	18.3	3.0			Water sample at 9:10 am
	9:15	15	20.0	1.7	18.3	3.0			Temp. = 42.5° F.
	9:20	20	20.0	1.6	18.4	3.1	46		59 secs. to fill 45 gallon drum
	9:25	25	20.0	1.5	18.5	3.2			Pump adjusted slightly
	9:30	30	20.0	1.4	18.6	3.3	45		45 gallons in 60 secs.
	9:40	40	20.0	1.3	18.7	3.4			
	9:50	50	20.0	1.2	18.8	3.5			Pumping well and observation wells
	10:00 am	60	20.0	1.1	18.9	3.6			Locations shown on attached sketch

Figure 4. Typical pump-test data - pumping well

RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water Level Measurements (field)

Location of project: Town of Cardium, Alta. — Test conducted by: Big Well Drilling Ltd. — Measured by: R. A. James

Well location: Lsd. or 1/4 SW Sec. 7 Tp. 58 R. 10 Mer. W 6th

Status: Observation Well #1 (pumping or observation well) — R = 300' East of pumping well #1 (distance from pumping well in feet and direction) — Date June 1/62 — Page 1

Date	Time hrs. & mins.	Elapsed time in mins.	Tape reading at Meas. Point	Tape reading at Water Level	Depth to water in feet	Draw-down in feet	Q = discharge gpm		Remarks (i.e. pump adjustments, water temp., static level, etc.)
May 31	6:10 pm		18.00	1.98	16.02				Static or nonpumping level
	7:10 pm		18.00	2.14	15.86				measurements
	10:10 pm		18.00	2.23	15.77				
June 1	12:10 am		18.00	2.29	15.71				Measurement by chalked steel tape
	6:10 am		18.00	2.30	15.70		Nil.		to nearest one-hundredth of a foot
	7:10 am		18.00	2.29	15.71				
	8:10 am		18.00	2.30	15.70				
	8:40 am		18.00	2.30	15.70				
	8:58 am		18.00	2.30	15.70		Observation		
June 1	9:00 am		18.00	2.30	15.70	0.0			Testing started at 9:00 a.m.
	9:01 am	1	18.00	2.29	15.71	0.01			
	9:02	2	18.00	2.28	15.72	0.02			
	9:03	3	18.00	2.27	15.73	0.03			
	9:04	4	18.00	2.25	15.75	0.05	Well		
	9:05	5	18.00	2.23	15.77	0.07			
	9:06	6	18.00	2.17	15.83	0.13			
	9:07	7	18.00	2.09	15.91	0.21			
	9:08	8	18.00	1.97	16.03	0.33			
	9:09	9	18.00	1.83	16.17	0.47			
	9:10	10	18.00	1.69	16.31	0.61			
	9:15	15	18.00	1.49	16.51	0.81			
	9:20	20	18.00	1.39	16.61	0.91			
	9:25	25	18.00	1.29	16.71	1.01			
	9:30	30	18.00	1.20	16.80	1.10			
	9:40	40	18.00	1.11	16.89	1.19			
	9:50	50	18.00	1.03	16.97	1.27			
	10:00 am	60	18.00	0.97	17.03	1.33			

Figure 5. Typical pump-test data - observation well

RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water Level Measurements (field)

Location of project: Town of Cardium, Alta.
Status: Observation Well (pumping or observation well)

Test conducted by: Big Well Drilling Ltd. Measured by: R. A. James
Well location: Lsd. or 1/4 SW Sec. 7 Tp. 58 R. 10 Mer. 6th
R = 300' east of pumping well #1 (distance from pumping well in feet and direction) Date June 3/62 Page 4

Date	Time hrs. & mins.	Elapsed time in mins.	Tape Reading at Meas. Point	Tape Reading at Water Level	Depth to water in feet	Draw-down in feet	Q = discharge gpm		Remarks (i.e. pump adjustments, water temp., static level, etc.)
June 3	9:00 a.m.	2880	32.00	1.60	31.40	15.70			Pump stopped
	9:01 a.m.	2881	32.00	5.60	26.40	10.70			Recovery
	9:02 a.m.	2882	32.00	8.40	23.60	7.90			Measurements by chalked steel tape to
	9:03 a.m.	2883	32.00	10.19	21.81	6.11			nearest one-hundredth of a foot.
	9:04 a.m.	2884	20.00	0.20	19.80	4.10			
	9:05 a.m.	2885	18.00	0.35	17.65	1.95			
	9:06 a.m.	2886	18.00	0.50	17.50	1.80			
	9:07	2887	18.00	0.60	17.40	1.70			Original static
	9:08	2888	18.00	0.70	17.30	1.60			June 1, 1962, @ 9:00 a.m. 15.70
	9:09	2889	18.00	0.75	17.25	1.55			
	9:10	2890	18.00	0.80	17.20	1.50			
	9:15	2895	18.00	0.85	17.15	1.45			
	9:20	2900	18.00	0.90	17.10	1.40			
	9:25	2905	18.00	0.96	17.04	1.34			
	9:30	2910	18.00	0.99	17.01	1.33			
	9:40	2920	18.00	1.01	16.99	1.29			
	9:50	2930	18.00	1.04	16.96	1.26			
	10:00	2940	18.00	1.06	16.94	1.24			
	10:15	2955	18.00	1.15	16.85	1.15			
	10:30	2970	18.00	1.25	16.75	1.05			
	10:45	2985	18.00	1.37	16.63	0.93			
	11:00	3000	18.00	1.45	16.55	0.85			
	11:30	3030	18.00	1.50	16.50	0.80			
	12:00 noon	3060	18.00	1.54	16.46	0.76			
	12:30 p.m.	3090	18.00	1.68	16.32	0.62			
	1:00 p.m.	3120	18.00	1.70	16.30	0.60			
	1:30 p.m.	3150	18.00	1.85	16.15	0.45			

Figure 6. Typical recovery-test data

Pumping-Rate Determination

For pumping tests that are run at rates of up to 100 gpm, the most satisfactory and simplest method of determining the rate is to discharge the pumped water into a container that has a known volume, such as a 45-gallon oil drum, and record the time required to fill the container.

If the pumping rate exceeds 100 gpm, it generally has to be determined in one of the following ways:

1. by standard orifice fittings on the discharge pipe;
2. by measuring the flow with a weir; or
3. by measuring the flow with a flowmeter on the discharge pipe.

All discharge pipes should have gate or globe valves with which to regulate the flow.

The pumping rate should be checked at regular intervals throughout the test, preferably at about the same time that the water-level measurements are made. This will enable a close watch to be kept on the pump, so that adjustments can be made if there is a marked decline or increase in the rate.

These methods of measuring flow rates are outlined in any standard water supply engineering text or water-well driller's handbook (Babbitt and Doland, 1955; or Anderson, 1955) and in Appendix C.

Discharging Water

Pumped water that is being discharged should be directed away from the test site in such a manner that the least inconvenience will result. It should not be discharged in the immediate vicinity of the well site because some of the water may leak back into the well, either through faulty well casing or through permeable ground. This discharged water would then give erroneous water-level measurements and the pumping-test data could not be relied upon for a suitable interpretation.

Step-Drawdown Pumping Test

A step-drawdown test is carried out on a completed production water-well and all the water-level measurements are made on the pumping well, either with an air line gauge or an electric tape.

In the step-drawdown test, the well is pumped for successive one-hour periods, initially at one-third of the rate used in the constant-rate-drawdown test, during the second period at two-thirds of that rate, and finally at the full rate. If, for any reason, these periods or pumping rates cannot be adhered to exactly, the actual periods and rates should be accurately recorded.

RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water-Level Measurements (field)

Test Conducted by: Big Well Drilling Ltd. Measured by: J. H. George

Location of project Cardium, Alberta Well location: Lsd. or 1/4 SW Sec. 7 Tp. 58 R. 10 Mer. W 6th

Status Pumping Well #1 R = 0' Date June 4, 1962 Page 1

(pumping or observation well) (distance from pumping well in feet and direction)

Date	Time hrs. & mins.	Elapsed time in mins.	Tape Reading at Meas. Point	Tape Reading at Water Level	Depth to water in feet	Draw-down in feet	Q = discharge gpm	Remarks (i.e. pump adjustments, water temp., static level, etc.)
June 4	6:00 a.m.		17.00	1.73	15.27	0		Static or nonpumping level (steel tape)
	8:00 a.m.		17.00	1.73	15.27	0	20	Step-drawdown test started 1st hour
	8:01 a.m.				15.4			@ 20 gpm.
	8:02 a.m.				15.5			
	8:03 a.m.				16.0			Measurements with electric tape
	8:50 a.m.				17.0			
	9:00 a.m.				18.0		40	Pumping rate increased to 40 gpm
	9:01 a.m.				19.5			@ 9:00 a.m. for 2nd step
	9:02 a.m.				20.6			
	9:50 a.m.				22.4			
	10:00 a.m.				23.2		60	Pumping rate increased to 60 gpm for
	10:01 a.m.				25.6			3rd step
	10:02 a.m.				26.4			
	10:03 a.m.				26.8			
								Complete series of measurements taken
								for each step, the same as for the first
								hour on constant-rate test. They are not
	10:40 a.m.				31.5			shown here as there is not enough room
	10:50 a.m.				32.8			to show whole test on one page.
	11:00 a.m.				33.5			

Figure 7. Typical step-drawdown-test data

During each one-hour period, the water-level measurements are to be taken as outlined for the first hour of the constant-rate-pumping test. See figure 7 for an example of typical step drawdown test data.

Bail-Test Procedure

The recommended procedure for bail testing an aquifer, usually carried out by the water-well driller, is given below:

1. Measure the depth to the water after the well has not been disturbed for several hours;

2. Start bailing at a constant rate; record the time the bailing starts, the number of full bailers each minute and the volume of water that each bailer contains;

3. The bailer should be lowered to the bottom of the hole at each trip. This will develop the well and permit a constant bailing rate to be maintained. Bailing should be continued for at least two hours, or until the water level is so near the bottom that only partially full bailers are pulled. If this happens, bailing should be stopped.

4. Record the time when the last bailer is pulled and begin taking water-level measurements immediately to determine the rate of recovery; the exact time that the water level is measured should be recorded, and readings should be taken at the intervals stated below after the bailing stops:

   a. every minute from 1 to 10 minutes
   b. every 5 minutes from 10 to 30 minutes
   c. every 10 minutes from 30 minutes to 2 hours.

If a measurement is missed, continue with the next. In some tests, for example, it may be possible to get readings only every 2 minutes immediately after the bailing stops. Figure 8 illustrates typical information obtained from a bailing test. This information sometimes may be used to calculate a preliminary value of the aquifer-transmitting capability and consequently of the well capacity.

In some instances the aquifer is capable of transmitting water so rapidly that bailing (maximum rate around 20 to 40 gpm) will have very little effect on the water level. In such a case a pump will have to be installed and run without a prior bail test. In every case, however, a well should have a pump test conducted on it, whether or not a bailing test has been performed.

RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water-Level Measurements (field)

Location of Project: Ray Donald Farm Well
Status: Pumping Well (pumping or observation well)

Test conducted by: Big Well Drilling Ltd. Measured by: J. H. George
Well Location: Lsd. or 1/4 8 Sec. 27 Tp. 58 R. 11 Mer. 6th
R = 0' (distance from pumping well in feet and direction) Date July 18/62 Page 1

Date	Time hrs. & mins.	Elapsed Time in mins.	Tape Reading at		Depth to water in feet	Draw-down in feet	Q = discharge gpm	Remarks (i.e. pump adjustments, water temp., static level, etc.)
			Meas. Point	Water Level				
	6:00 a.m.				17.8			Well cleaned out previous day and allowed to recover over night.
	7:00 a.m.				17.8			
July 18	8:00 a.m.	0			17.8		20	
	9:00 a.m.	60			57.6			Bailing rate = 20 gpm from 8:00 a.m. to 9:00 a.m.
	9:01 a.m.	61			49.9			
	9:02 a.m.	62			42.6			
	9:03 a.m.	63			36.8			Well bailed at one 10-gallon bail every 30 seconds for one hour.
	9:04 a.m.	64			31.9			
	9:05 a.m.	65			27.2			
	9:06 a.m.	66			24.8			
	9:07 a.m.	67			23.5			Bailing stopped @ 9:00 a.m.
	9:08 a.m.	68			22.4			Recovery measurements taken with electric tape
	9:09 a.m.	69			21.0			
	9:10 a.m.	70			21.6			
	9:15 a.m.	75			21.5			
	9:20 a.m.	80			21.4			
	9:25 a.m.	85			21.2			
	9:30 a.m.	90			21.1			
	9:40 a.m.	100			21.0			
	9:50 a.m.	110			20.3			
	10:00 a.m.	120			19.8			Measurements stopped @ 11:00 a.m. as well almost completely recovered.
	10:15 a.m.	135			19.0			
	10:30 a.m.	150			18.8			
	10:45 a.m.	165			18.1			
	11:00 a.m.	180			17.9			

Figure 8. Typical bail-test data

APPENDIX B. WATER-LEVEL MEASUREMENTS

Wetted-Tape Method

The depth to water is read to the nearest one-hundredth of a foot (0.01 ft.) using a steel measuring tape. The lower end of the tape is chalked (carpenter's blue chalk is suitable and easily obtained) and the tape lowered into the well until the lower end is in the water. A selected foot mark is held at some known measuring point on the well casing and then the tape is reeled in. The wetted length of the tape is subtracted from the footage at the known measuring point to determine the depth to the water. A weight of some kind attached to the end of the tape will aid in using it in the well. The wetted-tape method is one of the most precise ways of measuring water levels and should be used for measuring water levels in observation wells where possible.

Electric-Tape Method

The depth to water is measured to the nearest 0.05 ft by lowering a sonde into the well. When the tip of the sonde touches water, an electric circuit is completed which flashes a light or shows on a meter at the surface. The amount of cable in the well is equal to the depth to water. These electric measuring devices can be obtained commercially. The electric-tape method is generally used for determining the water level in a pumping well, and is also very useful in taking measurements after a bailing test to determine the rate of recovery.

Air-Line Method

The depth to the water is registered to the nearest foot on a pressure gauge at the ground surface. In this method, outlined by Anderson (1955), a small-diameter (1/8 or 1/4-inch) airtight, copper, galvanized iron or plastic tubing is inserted into the well to a depth that should be below the lowest anticipated water-level. Generally the air line is attached to the pump when it is installed in the well, with the length of the installed air line carefully measured. The air line is brought to the ground surface and fittings are attached to it, so that a pressure gauge and an ordinary tire air valve can be connected to it. The pressure gauge may read in pounds pressure or directly in feet. The air line is filled with air (either with a hand pump or air compressor) until the reading on the pressure gauge does not change. This reading can then be converted to feet, if the gauge is calibrated in pounds per square inch of pressure, by multiplying by 2.31. A diagrammatic representation of an air line gauge is presented in figure 9.

According to Anderson (1955) after air has been pumped into the air line and the maximum gauge reading obtained, this reading is equal to the pressure exerted by the column of water (B) standing outside the air line. The gauge reading in feet (which equals the height B) is then subtracted from the total vertical length of the air line (A) to obtain the depth to water (C) in feet below the centre of the gauge.

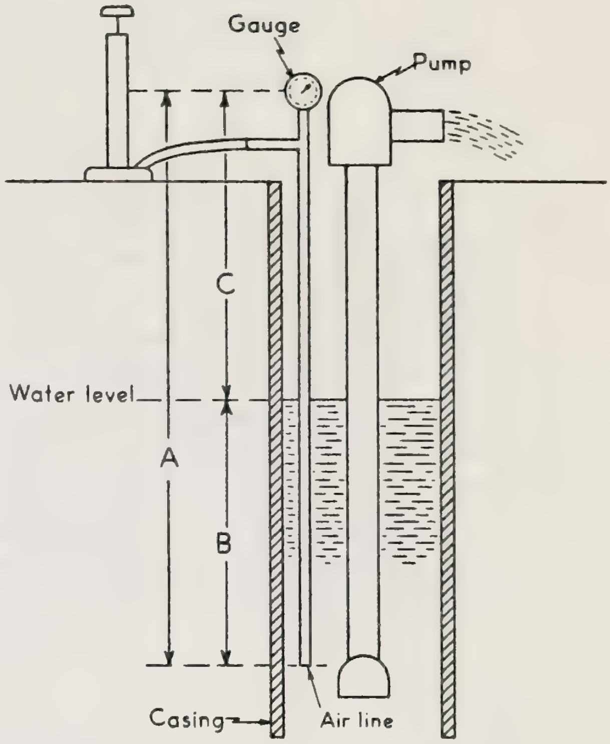


Figure 9. Air line water-level-measurement equipment (after Anderson, 1955, p. 124)

Automatic Water-Level Recorder

Commercial automatic water-level recorders can be obtained for measuring the water levels in wells. These are most useful installed on observation wells, because a continuous record of the water-level fluctuations can be obtained. The automatic water-level recorder has a balanced float which rises and falls with changes in the water level and these movements are recorded by a pen on a clock controlled chart. Different scale charts can be used and the automatic recorder is especially useful during the early part of pumping tests when the water level changes rapidly. Precise water-level measurements can be obtained using this method.

APPENDIX C. WATER-FLOW MEASUREMENTS

The following figures and tables are presented as a pumping-test aid for use in determining the flow of water from wells. All the tables on water-flow measurement have been converted to imperial gallons per minute, from U.S. gallons per minute.

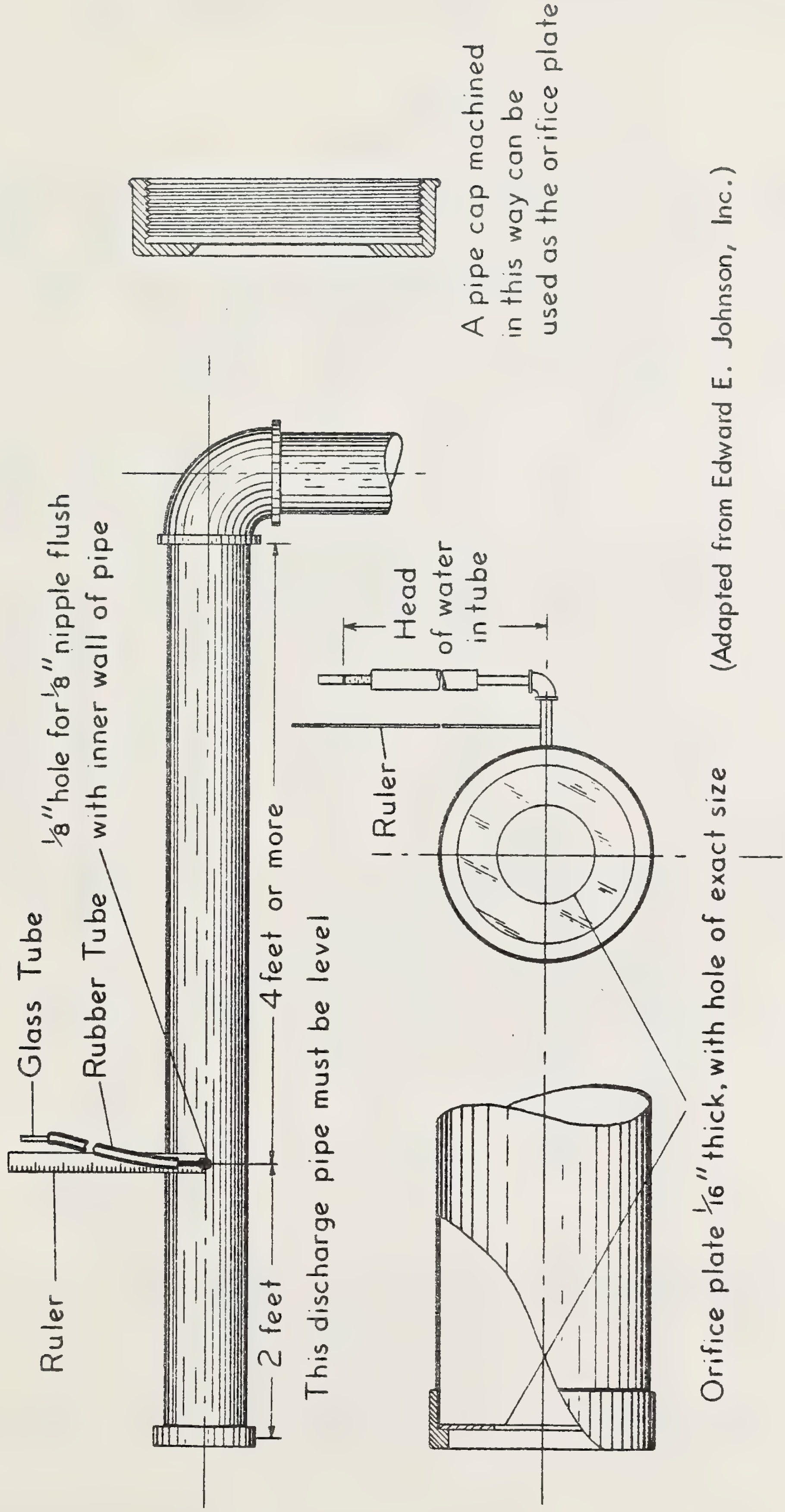


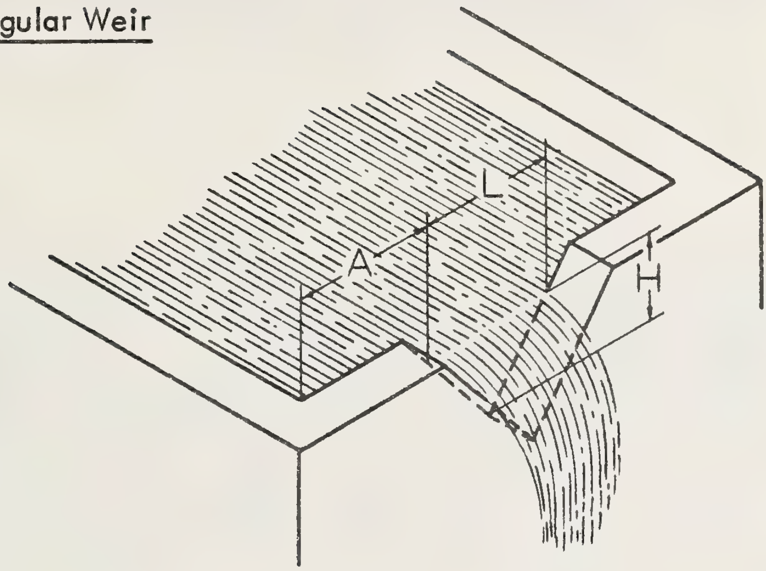
Figure 10. Orifice-flow-measurement equipment

Table 1. Discharge from Circular-Orifice Weirs*
(adapted from Edward E. Johnson Inc., and Anderson, 1955)

Head in inches	2 1/2" orifice 4" pipe	3" orifice 4" pipe	3" orifice 6" pipe	4" orifice 6" pipe	4" orifice 8" pipe	5" orifice 6" pipe	5" orifice 8" pipe	6" orifice 8" pipe	6" orifice 10" pipe	7" orifice 10" pipe	8" orifice 10" pipe
5	42	83	63	121	117	233	183	317	267		
6	50	90	68	133	125	254	200	340	288		
7	54	96	73	143	133	273	217	361	308		
8	58	102	72	154	142	292	233	382	329	500	742
9	61	107	83	162	150	310	248	403	350	528	827
10	64	111	87	171	158	327	263	423	371	555	867
11		117	91	179	167	343	275	444	391	582	900
12	71	122	95	187	173	358	288	463	408	607	933
14	77	131	102	202	187	387	313	499	442	654	995
16	82	139	110	214	198	412	334	530	473	698	1055
18	87	148	117	226	210	437	355	560	503	739	1113
20	92	156	123	237	222	457	374	590	530	777	1170
22	96	164	130	249	232	477	392	620	553	816	1226
24		171	137	258	242	497	407	647	577	852	1274
25	101	175	139	264	247	507	413	659	588	869	1297
26		178	142	269	252	517	420	671	600	887	1321
28		185	147	279	262	537	433	692	622	920	1367
30	112	192	152	288	271	557	447	714	644	952	1414
32		199	157	297	279	577	460	735	666	984	1460
34		205	162	307	287	596	473	756	687	1015	1507
35	121	208	164	312	290	605	480	766	697	1029	1531
36		212	167	317	295	616	487	776	706	1042	1554
38		217	171	325	302	632	500	796	722	1067	
40	129	222	175	334	309	651	513	816	739	1092	
42		227	178	342	317	667	526	834	755	1117	
44		232	182	350	323	683	537	852	771	1142	
45	137	234	185	354	327	690	543	862	778	1156	
46		237	187	357	331	697	549	871	787	1167	
48		242	191	367	338	712	560	889	802	1192	
50	144	247	195	373	344	727	572	907	818	1212	
52		252	198	381	351	740	583	925	833	1242	
54		256	203	387	357	753	595	942	848	1267	
55		258	205	391	361	760	601	950	856	1278	
56		261	207	393	364	766	606	958	863	1290	
58		264	210	400	371	773	612	976	877	1312	
60	158	270	214	407	377	790	626	992	890	1332	
62		273	218	413	384	801	636	1007	903		
64		277	222	420	391	812	646	1022	916		
65		279	223	424	393	817	651	1030	922		
66		282	226	427	396	823	656	1037	927		
68		286	229	433	402	835	666	1052	939		
70		291	233	437	409	847	676	1067	950		

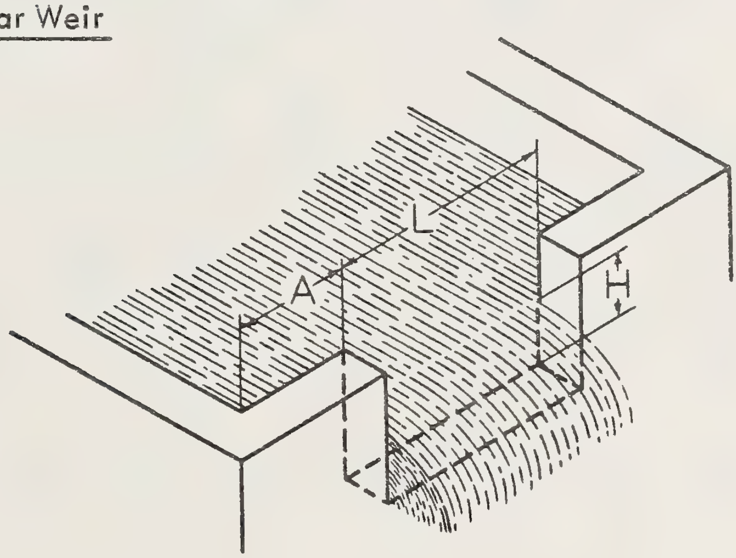
* Figures in table are in imperial gallons per minute

A. Triangular Weir



L = width of notch in feet at H distance above apex
H = head of water above apex of notch in feet
A = should not be less than 3/4 L

B. Rectangular Weir



L = length of weir opening in feet (should be 4 to 8 times H)
H = head on weir in feet (to be measured at least 6 ft. back of weir opening)
A = should be at least 3H

Figure 11. Weir-Flow-Measurement Equipment
(adapted from Anderson, 1955, p. 126, p. 127)

Table 2. Discharge from Triangular-Notch Weirs with End Contractions (adapted from Anderson, 1955, p. 127)

Head (H) in inches	Flow in imperial gallons per minute		Head (H) in inches	Flow in imperial gallons per minute		Head (H) in inches	Flow in imperial gallons per minute	
	90° notch	60° notch		90° notch	60° notch		90° notch	60° notch
1	1.82	1.06	6 3/4	217	125	15	1593	920
1 1/4	3.19	1.84	7	237	137	15 1/2	1727	997
1 1/2	5.04	2.91	7 1/4	258	149	16	1871	1080
1 3/4	7.41	4.27	7 1/2	282	162	16 1/2	2021	1167
2	10.3	5.96	7 3/4	306	177	17	2177	1257
2 1/4	13.9	8.01	8	331	191	17 1/2	2341	1352
2 1/2	18.1	10.4	8 1/4	357	207	18	2512	1450
2 3/4	22.9	13.2	8 1/2	385	222	18 1/2	2690	1553
3	28.5	16.4	8 3/4	415	239	19	2876	1610
3 1/4	34.8	20.1	9	444	257	19 1/2	3069	1772
3 1/2	41.9	24.2	9 1/4	476	275	20	3269	1888
3 3/4	49.7	28.7	9 1/2	508	293	20 1/2	3477	2008
4	58.5	33.7	9 3/4	542	313	21	3693	2133
4 1/4	68.1	39.3	10	578	334	21 1/2	3197	2262
4 1/2	78.5	45.3	10 1/2	653	377	22	4148	2395
4 3/4	90.0	51.9	11	733	423	22 1/2	4388	2533
5	102	60.0	11 1/2	820	473	23	3803	2676
5 1/4	116	66.6	12	911	526	23 1/2	4892	2825
5 1/2	130	74.9	12 1/2	1010	583	24	5156	2977
5 3/4	145	83.3	13	1114	643	24 1/2	5430	3135
6	161	93.3	13 1/2	1224	706	25	5710	3297
6 1/4	178	103	14	1340	774			
6 1/2	197	113	14 1/2	1463	845			

Table 3. Discharge from Rectangular Weirs with End Contractions (adapted from Anderson, 1955, p. 126)

Head (H) in inches	Flow in imperial gallons per minute for a weir length (L) of				Head (H) in inches	Flow in imperial gallons per minute for a weir length (L) of		
	1 foot	3 feet	5 feet	Each additional foot		3 feet	5 feet	Each additional foot
1	29.5	89.6	149.8	30.03	8	1948	3296	679
1 1/4	41.2	125.3	208.6	41.99	8 1/4	2034	3449	708
1 1/2	54.1	164.1	274.5	55.15	8 1/2	2116	3592	741
1 3/4	67.5	206.6	345.7	69.56	8 3/4	2213	3758	774
2	82.1	251.6	421.5	84.98	9	2304	2915	808
2 1/4	97.5	300.7	504	101.6	9 1/4	2396	4081	842
2 1/2	113.5	351.6	588.2	119.1	9 1/2	2487	4247	875
2 3/4	130.8	404.1	679.0	137.5	9 3/4	2583	4405	909
3	148.1	459.9	771.5	155.8	10	2679	4574	946
3 1/4	166.5	519.9	872.3	175.8	10 1/2	2899	4949	1025
3 1/2	185	579	972.2	196.6	11	3096	5294	1100
3 3/4	204.1	640.7	1076.4	217.4	11 1/2	3299	5648	1175
4	224.1	704.8	1186	239.9	12	3487	5969	1245
4 1/4	244.6	770.6	1299	263.3	12 1/2	3691	6327	1312
4 1/2	265	838.1	1413	287.4	13	3882	6673	1383
4 3/4	286.6	908.9	1529	311.6	13 1/2	4124	7090	1483
5	308.2	978.9	1654	337.4	14	4345	7481	1570
5 1/4	329.5	1051	1775	361.6	14 1/2	4561	7864	1654
5 1/2	351.2	1126	1901	387.4	15	4782	8264	1741
5 3/4	374.1	1201	2033	412.4	15 1/2	5011	8664	1803
6	397	1279	2166	439.9	16	5240	9081	1916
6 1/4		1360	2299	466.5	16 1/2	5469	9481	2008
6 1/2		1451	2433	496.5	17	5769	9972	2099
6 3/4		1521	2578	524.9	17 1/2	5948	10340	2199
7		1606	2716	556.5	18	6173	10750	2287
7 1/4		1690	2863	584.4	18 1/2	6411	11170	2378
7 1/2		1775	3007	613.2	19	6648	11610	2474
7 3/4		1864	3153	644.8	19 1/2	6898	12050	2574

APPENDIX D. HEALTH-UNIT LOCATIONS

Health Unit	Location
Alberta East Central	Stettler
Athabasca	Athabasca
Barons-Eureka	Coaldale
Chinook	Fort MacLeod
City of Lethbridge	Lethbridge
Drumheller	Drumheller
Edson	Edson
Foothills	High River
Grande Prairie	Grande Prairie
Jasper Place	15626 - Stony Plain Road, Jasper Place
Leduc-Strathcona	10426 - 81 Avenue, Edmonton
Medicine Hat	Medicine Hat
Minburn-Vermilion	Vermilion
Mount View	401 - 12 Ave., N.E., Calgary
North Eastern Alberta	St. Paul
Peace River	Peace River
Red Deer	Red Deer
Stony Plain-Lac Ste. Anne	Stony Plain
Sturgeon	12634 - Ft. Trail, Edmonton
Vegreville	Vegreville
Wetoka	Wetaskiwin

APPENDIX E. INFORMATION AVAILABLE FROM THE GROUNDWATER DIVISION

Groundwater Files*

1. Cardex files of water-well drillers' logs in the Province.
2. Records of flowing seismic shotholes drilled in the Province.
3. Records of groundwater-level fluctuations measured in different areas throughout the Province.
4. Geologic information pertaining to different aquifers.
5. Water-quality analyses from many water wells throughout the Province.
6. Information on well-completion methods and aquifer testing.
7. Industrial and municipal open-file reports dealing with the studies that have been made on the occurrence, movement and use of groundwater from many parts of the Province.
8. Papers on current groundwater research.

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* These files and records can be examined at the Research Council of Alberta in Edmonton.

Publications

A list of the publications on groundwater geology and hydrology by the Groundwater Division may be obtained by writing the Librarian, Research Council of Alberta, 87th Avenue and 114th Street, Edmonton. The publications can be purchased from the Research Council of Alberta if available.

APPENDIX F. SOME DEFINITIONS PERTAINING TO GROUNDWATER

Aquifer - A geologic formation or zone that transmits enough water to supply a well or spring. What is a good aquifer in one area may not be considered an aquifer at all in another area.

Artesian Aquifer - An aquifer in which water is "confined" by an overlying impervious bed and the water in a borehole penetrating the aquifer rises some height above the aquifer. The distance the water rises above the aquifer represents the pressure of the water in the aquifer.

Bail Test - The removal of water from a well at regular timed intervals, using a long cylindrical container or bailer with a valve at the bottom.

Bedrock - Any relatively solid rock, such as the Edmonton formation, underlying soil, sand, clay, etc.

Capacity - The number of gallons per minute a well can produce on a continuous long-term basis.

Cone of Depression - The inverted cone-shaped surface of the water levels in the vicinity of a pumping well caused by the decrease in pressure in the aquifer due to pumping.

Confined Aquifer - See "Artesian Aquifer".

Cretaceous - A period of geologic time 70 to 135 million years ago.

Drawdown - The lowering of the water level in a well due to pumping.

Flowing Artesian Well - A well which discharges water freely above the land surface under its own natural pressure.

Glacial - Pertaining to, characteristic of, produced or deposited by, or derived from a glacier.

Groundwater - Water in the zone of saturation.

Hydrology - The science that relates to the water of the earth.

Hydrostatic Level - For a given point in an aquifer, the height of a vertical column of water of unit cross section, the weight of which is equal to the hydrostatic pressure at that point.

Nonpumping Level - The water level in a well that is not being pumped, nor being used as an observation well during the test of a nearby well, and that is not recovering from the effects of previous pumpage or tests. Such a water level is frequently referred to as the static level colloquially, but this term is a misnomer because natural phenomena can give rise to fluctuations of the nonpumping level. During the course of a pumping test the nonpumping level may also be defined as the water level that would be observed if the test were not taking place.

Observation Well - A well in which water level changes due either to pumping or natural causes are observed.

Permeability - The property of a rock that enables water to move through it.

Porosity - The percentage of pore space in a rock or the property of a rock that enables it to hold water.

Recovery - The return of the water level in a well to its static or nonpumping level after pumping has stopped.

Specific Capacity - The number of gallons per minute a well will produce for each foot of stabilized drawdown.

Static Level - See "Nonpumping Level".

Stratigraphic Log - A description of the nature and thickness of geologic formations or materials penetrated in a borehole.

Surging - The cleaning and development of a water-bearing formation by alternately forcing water into the formation and then pumping it out. Surging can be accomplished by mechanical means such as the rapid up-and-down movement of a plunger within the well casing. A well can also be surged with compressed air.

Tertiary - A period of geologic time one to seventy million years ago.

Unconfined Aquifer - See "Water-Table Aquifer".

Water Table - The level below which all pore space is filled with water.

Water-Table Aquifer - An aquifer for which there is no confining bed and the water level in the aquifer represents the true elevation of the water level.

<u>Zone of Saturation</u> - The zone below the water table.

Some of these definitions were adapted in part and in whole from the "Glossary of Geology and Related Sciences", American Geological Institute, and from Meinzer (1923b). The readers are referred to these publications for other definitions not included in the above list.

APPENDIX G. CONVERSION TABLES
(from Anderson, 1955, p. 10, 11)

Flow

Unit		Equivalent						
		U.S. gallons per day	Imp. gallons per day	Cubic feet per day	U.S. gallons per minute	Imp. gallons per minute	Acre feet per day	Cubic feet per second
1 U.S. gallon per day	=	ONE	.8333	.1337	.0006944	.0005787	.000003069	.000001548
1 imp. gallon per day	=	1.200	ONE	.1605	.0008333	.0006944	.000003683	.000001856
1 cubic foot per day	=	7.4805	6.233	ONE	.005195	.004327	.00002296	.00001157
1 U.S. gallon per minute	=	1440	1200	192.5	ONE	.8333	.00442	.00223
1 imp. gallon per minute	=	1728	1440	231.12	1.200	ONE	.00530	.00267
1 acre foot per day	=	325,850	271,542	43,560	226.28	188.57	ONE	.5042
1 cubic foot per second	=	646,323	538,860	86,400	448.83	374.03	1.9835	ONE

Volume

Unit		Equivalent							
		Cubic centimeters	Cubic inches	Liters	U.S. gallons	Imp. gallons	Cubic feet	Cubic yards	Cubic meters
1 cu. centimeter	=	ONE	.06102	.001	.0002642	.0002201	.00003531	.000001308	.000001
1 cu. inch	=	16.39	ONE	.016387	.004329	.003607	.0005787	.00002143	.00001639
1 liter	=	1000	61.0234	ONE	.26417	.22008	.03531	.001308	.001
1 U.S. gallon	=	3785.4	231	3.7854	ONE	.8333	.13368	.00495	.003785
1 imp. gallon	=	4542.5	277.274	4.5425	1.2000	ONE	.16046	.00594	.00454
1 cubic foot	=	28,317	1728	28.317	7.4805	6.2321	ONE	.03704	.02832
1 cubic yard	=	764,560	46,656	764.56	201.974	168.267	27	ONE	.76456
1 cubic meter	=	1,000,000	61,023	1000	264.17	220.083	35.3145	1.30794	ONE

Length

Unit		Equivalent							
		Centimeters	Inches	Feet	Yards	Meters	Rods	Kilometers	Miles
1 centimeter	=	ONE	.3937	.0328	.01093	.01	.00199	.00001	.00000621
1 inch	=	2.54	ONE	.0833	.0278	.02540	.00505	.0000254	.0000158
1 foot	=	30.48	12	ONE	.33333	.30480	.0606	.000305	.000189
1 yard	=	91.44	36	3	ONE	.91440	.18181	.000915	.000568
1 meter	=	100	39.37	3.2808	1.0936	ONE	.1988	.001	.000621
1 rod	=	502.9	198	16.5	5.5	5.0292	ONE	.00503	.00312
1 kilometer	=	100,000	39,370	3280.8	1093.6	1000	198.83	ONE	.62137
1 mile	=	160,935	63,360	5280	1760	1609.3	320	1.6093	ONE

Area

Unit		Equivalent							
		Square centimeters	Square inches	Square feet	Square yards	Square meters	Square rods	Acres	Square miles
1 sq. centimeter	=	ONE	.155	.001076	.0001196	.0001	.000003953	-	-
1 sq. inch	=	6.452	ONE	.00694	.0007716	.0006452	.00002551	-	-
1 sq. foot	=	929	144	ONE	.1111	.0929	.003673	.00002296	-
1 sq. yard	=	8361	1296	9	ONE	.8361	.03306	.0002066	-
1 sq. meter	=	10,000	1550	10.76	1.196	ONE	.0395	.0002471	-
1 sq. rod	=	252,908	39,204	272.25	30.25	25.29	ONE	.00625	.000009766
1 acre	=	40,465,284	6,272,640	43,560	4840	4047	160	ONE	.001563
1 sq. mile	=	-	-	27,878,400	3,097,600	2,589,998	102,400	640	ONE